

Lecture Module - Electrical Signals

ME3023 - Measurements in Mechanical Systems

Mechanical Engineering

Tennessee Technological University

Module 4 - Electrical Signals

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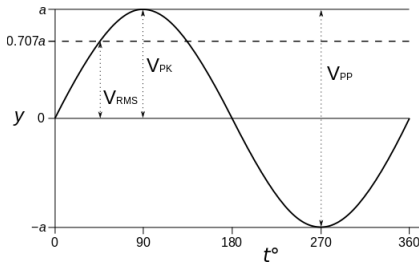
- Topic 1 - Classification of Signals
- Topic 2 - Signal Analysis
- Topic 3 - Sampling and Aliasing

Topic 1 - Classification of Signals

- Introduction to Signal Concepts
- Analog, Discrete, or Digital
- Static or Dynamic
- Deterministic or Non-Deterministic

Introduction to Signal Concepts

Signal, Amplitude, and Frequency

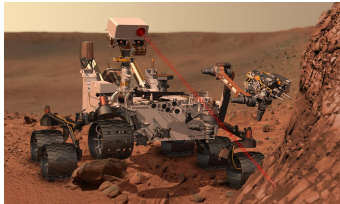


The shape and form of a *signal* are often referred to as its *waveform*. The *waveform* contains information about the magnitude and *amplitude*, which indicate the size of the input quantity, and the *frequency*, which indicates the way the *signal* changes in time.

Text: Theory and Design for Mechanical Measurements

Introduction to Signal Concepts

A *signal* is the physical information about a measured variable being transmitted between a process and the measurement system, between the stages of a measurement system, or as the output from a measurement system.



Analog, Discrete, or Digital

- Analog Signal- magnitude is continuous in time
- Discrete Time Signal- magnitude at points in time
 - sampling at repeated time intervals
- Digital Signal- exists in discrete points in time
 - magnitude is also discrete

Analog, Discrete, or Digital

Analog describes a signal that is continuous in time. Because physical variables tend to be continuous, an analog signal provides a ready representation of their time-dependent behavior.

Examples: voltage in a circuit

*...a **discrete time** signal, for which information about the magnitude of the signal is available only at discrete points in time. A discrete time signal usually results from the sampling of a continuous variable at repeated finite time intervals.*

Examples:

A *digital* signal has two important characteristics. First, a digital signal exists at discrete values in time, like a discrete time signal. Second, the magnitude of a digital signal is discrete, determined by a process known as *quantization* at each discrete point in time.

Examples:

Static or Dynamic

Signals may be characterized as either static or dynamic. A static signal does not vary with time.

A dynamic signal is defined as a time-dependent signal. In general, dynamic signal waveforms, $y(t)$, may be classified as shown in Table 2.1.

Static or Dynamic

Deterministic or Non-Deterministic

A deterministic signal varies in time in a predictable manner, such as a sine wave, a step function, or a ramp function, as shown in Figure 2.5. A signal is steady periodic if the variation of the magnitude of the signal repeats at regular intervals in time. Also described in Figure 2.5 is a non-deterministic signal that has no discernible pattern of repetition. A non-deterministic signal cannot be prescribed before it occurs, although certain characteristics of the signal may be known in advance.

Deterministic or Non-Deterministic

Table 2.1 Classification of Waveforms

I. Static	$y(t) = A_0$
II. Dynamic	
Periodic waveforms	
Simple periodic waveform	$y(t) = A_0 + C \sin(\omega t + \phi)$
Complex periodic waveform	$y(t) = A_0 + \sum_{n=1}^{\infty} C_n \sin(n\omega t + \phi_n)$
Aperiodic waveforms	
Step ^a	$y(t) = A_0 U(t)$ $= A_0 \text{ for } t > 0$
Ramp	$y(t) = A_0 t \text{ for } 0 < t < t_f$
Pulse ^b	$y(t) = A_0 U(t) - A_0 U(t - t_1)$
III. Nondeterministic waveform	$y(t) \approx A_0 + \sum_{n=1}^{\infty} C_n \sin(n\omega t + \phi_n)$

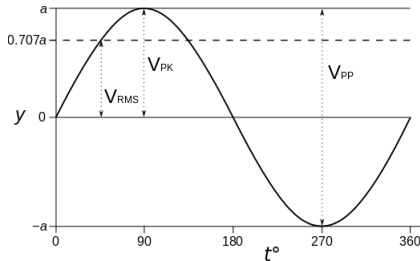
^a $U(t)$ represents the unit step function, which is zero for $t < 0$ and 1 for $t \geq 0$.

^b t_1 represents the pulse width.

Topic 2 - Signal Analysis

- Signal Mean Value
- Power Dissipation
- Signal Root Mean Square (RMS) Value
- Discrete-Time or Digital Signals

Signal Mean Value



Mean Value

$$\bar{y} \equiv \frac{\int_{t_1}^{t_2} y(t) dt}{\int_{t_1}^{t_2} dt}$$

Signal Mean Value

Dissipation - Time Rate of Energy Dissipation

$$P = I^2 R$$

Total Electrical Energy

$$E = \int_{t_1}^{t_2} P dt = \int_{t_1}^{t_2} [I(t)]^2 R dt$$

Power Dissipation

- For a cyclically alternating electric current, RMS is equal to the value of the direct current that would produce the same average power dissipation in a resistive load.
- In Estimation theory, the root mean square error of an estimator is a measure of the imperfection of the fit of the estimator to the data.
- The RMS value of a signal having a zero mean is a statistical measure of the magnitude of the fluctuations in the signal.

Signal Root Mean Square (RMS) Value

$$(I_e)^2 R(t_2 - t_1) = \int_{t_1}^{t_2} [I(t)]^2 R dt$$

$$I_e = \sqrt{\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} [I(t)]^2 dt}$$

$$y_{rms} = \sqrt{\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} [y]^2 dt}$$

Signal Root Mean Square (RMS) Value

$$\bar{y} = \frac{1}{N} \sum_{i=0}^{N-1} y_i$$

$$y_{RMS} = \sqrt{\frac{1}{N} \sum_{i=0}^{N-1} y_i^2}$$

Signal Root Mean Square (RMS) Value

Discrete-Time or Digital Signals

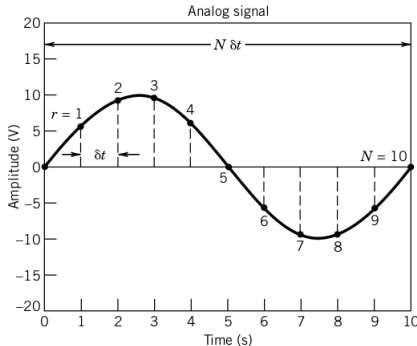
Discrete-Time or Digital Signals

Topic 3 - Sampling and Aliasing

- Sampling
- The Aliasing Phenomenon
- Example by Hand
- MATLAB Example

Sampling

... A discrete time signal usually results from the sampling of a continuous variable at repeated finite time intervals. ...



Discrete time signal	
$\{y(r\delta t)\}$	
r	Discrete data
0	0
1	5.9
2	9.5
3	9.5
4	5.9
5	0
6	-5.9
7	-9.5
8	-9.5
9	-5.9
10	0

The Aliasing Phenomenon

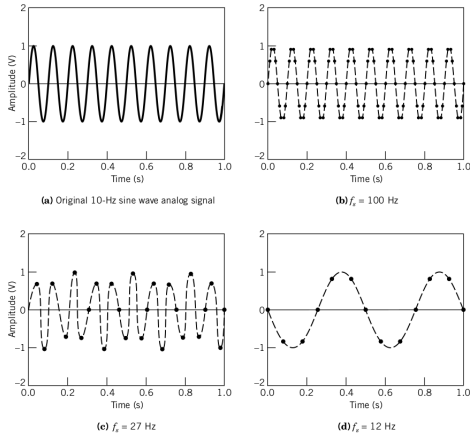


Figure: Theory and Design for Mechanical Measurements Ch. 7

Example by Hand

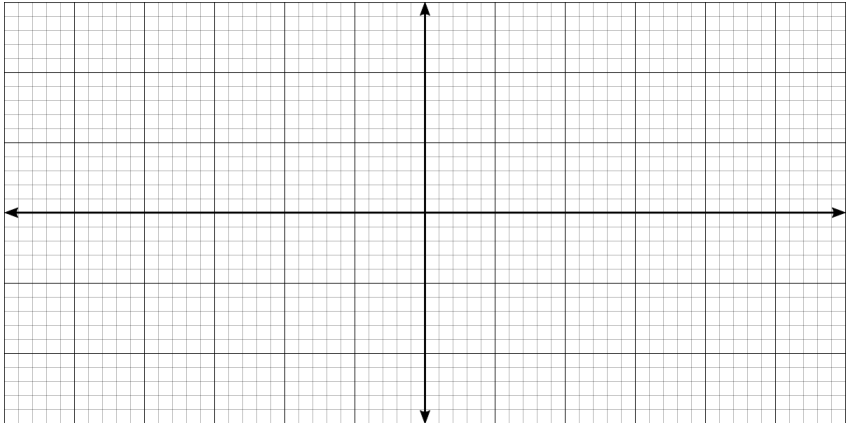


Image: T.Hill

Example by Hand

MATLAB Example

Activity: Sampling Demonstration

Use the MATLAB program provided to accomplish the following:

- ❶ Plot a sinusoidal signal $y(t) = A \sin(\omega \cdot t) = A \sin(2\pi f \cdot t)$ with an amplitude $A = 10$ (units) and frequency $f = 1000$ (Hz). This is the *ideal signal* source.
 - Include axis labels and gridlines.
 - Choose amplitude and time scales so that 15 to 20 periods or the waveform are shown.
- ❷ Simulate the sampling of the signal by plotting the same function with a reduced time step. Plot the sampled signal on the same figure. Use a different marker and include a legend to differentiate the signals.
- ❸ Use your code to determine the minimum sampling frequency required to measure the following quantities (note: use the sampled signal only, the *ideal signal* is not accessible).
 - Frequency of the *ideal signal*
 - Amplitude of the *ideal signal*

Deliverables: Submit answers to all questions to the appropriate ilearn folder. If you work with a partner, include all names with the responses. All group members must submit the assignment.

MATLAB Example